



ASSESSMENT OF LOBSTER (*HOMARUS AMERICANUS*) IN LOBSTER FISHING AREA (LFA) 34

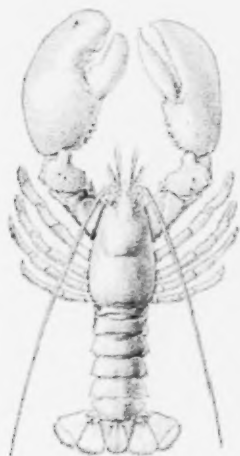


Figure 1. Lobster Fishing Areas (LFA) 34 and adjacent LFAs.

Context

The landed value of the lobster fishery in Atlantic Canada (\$396 million in 2010) is the highest of any fishery in Canada. Landings in Lobster Fishing Areas (LFA) 34 (Figure 1) have reached record highs in recent years. The status of the lobster resources in LFA 34 was last assessed in 2006. DFO's Fisheries and Aquaculture Management has requested updated information on the status of the LFA 34-38 lobster stocks.

A review of the Assessment Framework was held for LFAs 34-38 on July 10-12, 2012, in Digby, Nova Scotia. The objectives were to describe the basis of the management units in the context of stock structure; to identify strengths and weaknesses of fishery and survey data inputs; to present preliminary analyses of indicators of Fishery Performance, Abundance, Reproduction and Fishing Pressure; to review relevant biological and ecological information; to present the rationale for current landings-based reference points and potential alternatives; and to develop the assessment schedule. One outcome of the Framework review was the confirmation of two stock assessment units: LFA 34 and LFAs 35-38.

This Science Advisory Report is from the February 12-14, 2013, Review of Framework and Assessment for LFA 34-38 Lobster Stocks: Part 2 – Assessment. The objectives were to assess the stock status of the LFA 34-38 lobster stocks as of the end of the 2011-2012 seasons, including status in relation to reference points identified in the Assessment Framework; to estimate the level of incidental catch (including lobster), the retention of non-lobster species, and to report on information available on the survival of discarded species; as well as to provide implications for fishery management of the current estimates of the 50% size at onset of maturity for females, and other indicators of stock reproduction. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada \(DFO\) Science Advisory Schedule](#) as they become available.

SUMMARY

The Fishery

- Lobster (*Homarus americanus*) landings in Lobster Fishing Area (LFA) 34 in 2011/12 (23,292 t) are a record high at 2.7 times the 50-year annual mean (1961 to 2010: 8,575 t), and are 1.4 times higher than 2004/05 (latest year in the 2006 assessment).
- There has been a shift to a higher proportion of landings originating from midshore and offshore portions of LFA 34. Landings in the nearshore still comprise the bulk of the landings (63%) but have increased by a factor of just 1.2 since 2004/05. In the midshore and offshore, landings doubled relative to 2004/05.
- Total fishing effort as measured in terms of trap hauls has not increased since 2004/05. There have been spatial shifts in fishing effort and commercial catch rates that explain the spatial shift in landings.
- Commercial catch per unit effort (CPUE) in 2011/12 (1.1 kg/trap haul) increased substantially from 2004/05 (0.74 kg/trap haul) and from 1998-99 (0.58 kg/trap haul).
- Downward shifts in size structure were evident for some areas in the nearshore and midshore. There was no indication of a downward shift in size structure in the offshore.

Assessment

- Two fishery dependent indicators of the abundance of legal sizes (landings and commercial CPUE) are at record highs.
- A standardized CPUE index and a Temperature Corrected Abundance Index both indicate the abundance of sublegal lobsters in the last 2-3 years is the highest since 1999-00.
- The increasing trend in the summer Research Vessel survey, number of lobsters per tow in the Eastern Gulf of Maine area, is consistent with the increasing trend in lobster landings in LFA 34.
- The mean number of lobsters per tow in a joint industry/DFO trawl survey (ITQ survey) in LFA 34 has increased since 2000, with the highest values in the last 3 years. Catch rates are much higher in the nearshore, with a mean of over 240 lobsters per tow in each of the last 3 years, compared to 8-15 lobsters per tow in the midshore and less than 5 in the offshore.
- Exploitation rates in LFA 34 overall (0.8 for females) have not increased since 2000-01 but are high relative to other lobster assessment areas. There is mixed evidence for increased exploitation in the nearshore in the last 10-12 years.
- A truncated size distribution observed in the nearshore for decades suggests that exploitation rates have been high nearshore for many years. Exploitation rate is lower in the offshore portion of LFA 34 (0.49 for females) and has not increased since 2000-01.
- Size at onset of 50% maturity for 2011 was estimated at 96.5 mm carapace length in Lobster Bay, which is similar to a previous estimate of 95 mm. Only a small portion of females below the minimum legal size reach maturity.
- Despite increases in lobster abundance, the potential and observed egg production indices for subareas of the nearshore and midshore for the most recent time period showed no increase relative to the 1990-1995 time period.

- A precautionary approach proposed for lobster in LFA 34 utilizes reference points for the abundance of legal sizes (landings, commercial catch rate) and the abundance of legal and sublegal sizes combined (ITQ survey). These indicators are above their Upper Stock References (USR), indicating that the lobster stock in LFA 34 is in the healthy zone.
- Landings-based reference points are based on the median of lobster landings from 1985-2009. The Upper Stock Reference (USR) is 8,867 t. The 3-year running mean of landings is 21,147 t for the season ending 2011-12, putting LFA 34 lobster in the healthy zone, well above this USR.
- A proposed USR based on commercial CPUE is 80% of the median CPUE for the period 1998-99 to 2008-09. The current 3-year running mean (1.0 kg/trap haul) is well above the USR (0.62 kg/trap haul).
- A proposed fishery independent USR for legal and sublegal lobster abundance is 80% of the median catch rate in the ITQ survey for the period 1996-2009. The current 3-year running mean (71.9) is well above the USR (19.0 lobsters per tow).
- Environmental conditions for lobster production appear very favorable. High exploitation rates in the nearshore portion of LFA 34 have not inhibited the substantial increases in abundance in the last 10-12 years. Given that the environmental conditions remains favorable for lobster, the current levels of fishing effort do not appear to threaten the sustainability of lobster stocks in LFA 34.
- The percentage of reproduction contributed by larger females (>100 mm carapace length) is low and has likely declined relative to 20 years ago. Since it is uncertain how long favorable environmental conditions will continue, it is recommended that consideration be given to implement measures that increase egg production from larger sizes.

Ecosystem Considerations

- Based on previous patterns in the North Atlantic Oscillation, warmer than average water temperatures might be expected in LFA 34 in the next few years. In terms of longer term trends in temperature, there is a slightly increasing trend in the Bay of Fundy that may be significant, but the Halifax station indicates no long term trend in temperature.
- The trends in the summer Research Vessel survey biomass indices for potential predators of lobster (e.g. Atlantic wolffish, cod, cusk, haddock, longhorn sculpin, sea raven, spiny dogfish, white hake) indicate most are at low levels relative to their long-term means.
- The main species caught as incidental catch in the fishery were those that can be retained for bait and sale: Jonah crab (male only), rock crab (male only) and various sculpin/sea raven species. Other major species included cusk, cod, hermit crabs and whelks. The total incidental catch and incidental catch of non-retainable species represent 15% and 4.2% of the total lobster landings respectively. Lobster discards (post-release survival known to be high) were estimated at 0.7 kg for each 1.0 kg of lobster landed or 14,634 t (2009-10). Undersize lobsters account for approximately 97% of the lobster discards.
- The area affected by lobster traps (fishery footprint) in any given year in LFA 34 as a whole is calculated to be less than 0.1% of the total area.

BACKGROUND

Lobster Biology

Off southwestern Nova Scotia and the Bay of Fundy, most female lobsters mature between 90 and 105 mm carapace length (CL). The mature female mates after molting in midsummer and, in the following summer, produces eggs that attach to the underside of the tail. The eggs are carried for 10-12 months and hatch mainly in July or August. The larvae are planktonic for a few weeks to a month or more depending on temperature. There are 3 larval stages followed by a postlarval stage ("Stage 4") that is planktonic for a few days until it begins diving to the bottom to begin the benthic phase of life. Once the post larvae find suitable shelter on the bottom, they tend to remain in or near the shelter to avoid predation. As lobsters moult and become larger, they leave their shelters more often to forage.

Off southwestern Nova Scotia and the Bay of Fundy, lobsters are thought to take 8-10 years on average to reach the legal size of 82.5 mm CL, but lobster age at size may be quite variable based on recent studies. The maximum age of lobsters is unknown, but, based on growth information and long term holding studies, it is believed to be in the range of 50 years. Growth increments at moult are dependent upon size, sex and maturity with the mean growth increment for males and immature females between 12-16%, while mature females exhibit a declining percentage increase with size as more energy is invested in egg production.

Lobsters seasonally migrate to shallower waters in summer and deeper waters in winter. Over most of the lobster's range, these movements amount to a few kilometers; however, in the Gulf of Maine, the offshore regions of the Scotian Shelf and off New England, lobsters can undertake long distance migrations of tens to hundreds of kilometers.

Benthic stage lobsters are omnivorous, being mostly predators but scavenging prey items when available. Examination of juvenile and adult lobster stomach contents has found a wide variety of benthic organisms, including gastropods, bivalves (scallops, clams, mussels), chitons, crustaceans (e.g. rock crab), starfish and brittle stars, sea urchins, various marine worms (polychaetes), fish and occasionally plant material. Lobsters are also opportunistic feeders on fish eggs, discarded lobster shells and dead animals including fish, marine mammals and bait in lobster traps.

Stock Assessment Unit

Based on the degree of spatial and temporal integrity of population characteristics, Lobster Fishing Area (LFA) 34 is assessed independently from LFAs 35-38 (Bay of Fundy). There is some exchange of lobsters at the benthic stage between LFA 34 and the Bay of Fundy, but LFA 34 is large, has some genetic structure, and appears to receive a limited portion of its larvae from the Bay of Fundy. In addition, LFA 34 landings trends have differed from those of the Bay of Fundy.

Lobster stock structure in Atlantic Canada is currently being evaluated through a variety of approaches. While there may not be substantial changes to the current perspective, these studies will increase understanding of the levels of differentiation at different scales, and will test the findings from previous studies on larval exchange rates.

The Fishery

LFA 34, off Southwest Nova Scotia (Figure 1), has the highest landings and the most participants of any LFA in Canada. Commercial lobster fishing began in the mid-1800s, and annual lobster landings in the Gulf of Maine were first recorded in 1893. Landings peaked in 1898 and were followed by a decrease to 1,600 t in the early 1930s (Figure 2). Landings rose following World War II, varying between 2,200 and 4,500 t until the 1980s. Landings began a long-term increase in the 1980s and recent landings are at record highs. This increasing trend is part of a pattern that extended over most of the range of lobster in the western Atlantic.

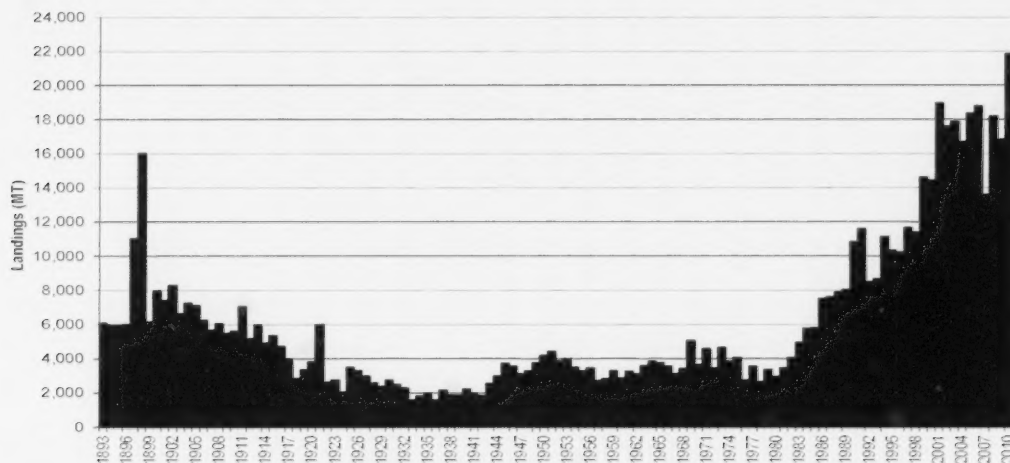


Figure 2. Annual lobster landings by the commercial fishery in LFA 34, 1893 to 2011.

Fishing prior to the early 1980s occurred in traditional nearshore grounds but has since expanded to include the entire LFA from the shallow near-shore areas to deep water areas just inside the 92 km (50 nautical miles) offshore lobster line.

A unique feature of LFA 34 and other Gulf of Maine lobster fisheries is the presence of a deepwater component. Beginning in the late 1970s, a few nearshore vessels in LFA 34 began to expand out from the traditional nearshore grounds (<55 m depth) and fished German Bank, Browns Bank, and the Tusket Basin. By the mid-1980s, approximately 100 vessels were fishing this deepwater area referred to as the midshore. This number remained relatively constant into the mid-1990s. Since then there has been an increase in the number of larger vessels capable of fishing further from shore and in almost any weather.

The fishery is managed by input controls including a minimum size carapace length, prohibition on landing of both egg-bearing and V-notched females, limited entry, a season between the last Tuesday in November through to May 31, and a trap limit of 375 from November to March and 400 in March to May (Table 1). Other management measures include the requirement for escape vents to allow escapement of sublegal sizes, and biodegradable trap mechanisms to mitigate ghost fishing by lost traps.

Table 1. Seasons, trap limits, licenses (as of January 2013) and size limit for LFA 34

Fishing Season	Last Monday in November to May 31
Number of traps per Category A License	375: 1st day of season - March 31 400: April 1 - May 31st
Number of traps per Category A Partnerships	563: 1st day of season - March 31 600: April 1 - May 31st
Category A Licences	860
Category A Partnerships	90
Category B	0
Commercial Communal Category A	27
Commercial Communal Partnership	2
Minimum legal size	82.5 mm carapace length

ASSESSMENT

Data Sources

Data sources used in this assessment are as follows:

Historical landings and landings from various sources; effort and catch rate from Lobster Catch and Settlement Reports (logbooks), begun in fall 1998.

Samples of the trap catch both at sea (total catch) and dockside (commercial catch only) to estimate size, sex and reproductive status (at-sea samples only).

The Fishermen and Scientists Research Society (FSRS) recruitment trap project. Begun in LFA 34 in fall 1999. Volunteer fishermen keep daily records of lobster count, size and sex in two standard traps.

Annual DFO Science summer Research Vessel (RV) survey from 1970-present.

Annual joint industry/DFO groundfish survey (ITQ survey), which records lobster as bycatch. This is a fixed station bottom trawl survey that began in 1995.

Annual survey for scallops, which began in 1982 and captures lobsters as a bycatch.

LFA 34 is a large and diverse fishing area, with specific Grid Groups (GG) identified for assessment purposes (Figure 3). These Grid Groups were based on nearshore, midshore and offshore areas that were further divided into northern and southern components. Additional subdivisions (A and B) of GG 2 and 4 were based on known size differences and the history of fishery.

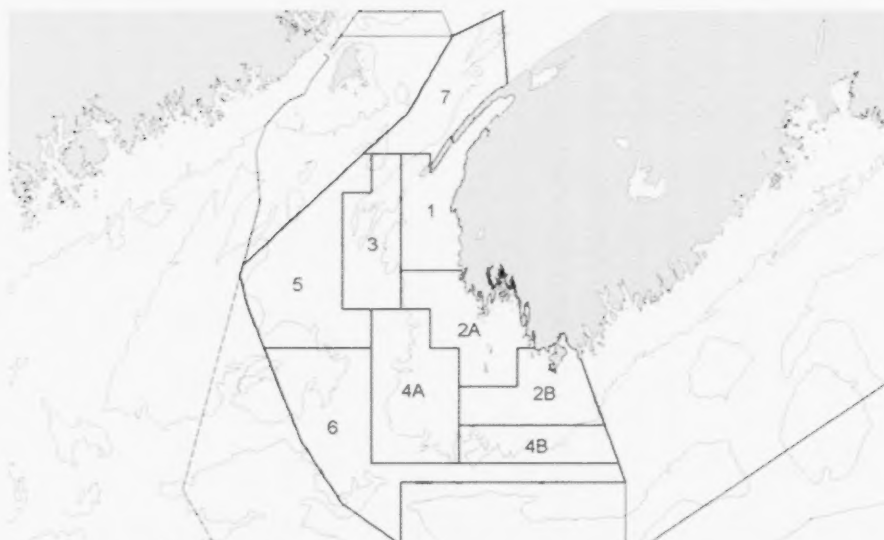


Figure 3. Grid Groups from combinations of 10 minute grids in LFA 34 logbooks.

Fishery Performance

Landings and catch rate have been used as abundance indicators; trends in these measures are reported, as well fishing effort and the size of lobsters in commercial traps.

Fishery Landings

Lobster landings in LFA 34 in 2011/12 are 2.7 times the 50-year annual mean (8,575 t), 1.4 times higher than 2004/05 (latest year in the 2006 assessment), and the last 3 years are the highest on record (Table 2). Considering the period from 1975-76 to 2011-12, eight of the last ten years are in the upper quartile; the other two years were in the third quartile.

Within the LFA 34 Grid Groups, spatial shifts in landings are evident (Figure 4). Most Grid Groups have trended upwards, but GG 2A (Lobster Bay area) has trended downward since 2001-02. Landings in GGs 2B and 4B have increased.

Landings from the midshore (GGs 3, 4A, 4B) and offshore (GGs 5, 6) have increased substantially relative to the nearshore (GGs 1, 2A, 2B, 7) (Table 3). There has been a shift to a higher proportion of landings originating from midshore and offshore portions of LFA 34. Landings in the nearshore still comprise the bulk of the landings (63%) but have increased by a factor of just 1.2 since 2004/05. In the midshore and offshore, landings doubled relative to 2004/05. This continues a trend since data from logbooks became available in 1998/99. Relative to 1998/99, 2011/12 landings in the inshore increased by 1.3 times, while landings increased to a much greater extent in the midshore (5.8 times) and the offshore (7.9 times).

Table 2. LFA 34 landings from the 1975-76 season to the 2011-12 season, as of Jan 1, 2013. Each cell is coloured depending on whether it is below the 25th percentile (black), between the 25th and 75th percentiles (grey) or above the 75th percentile (white). Values include commercial communal removals. Food, Social and Ceremonial (FSC) landings are not included but, given the effort deployed, are expected be no more than of 0.1-0.5% of the totals in recent years.

FISHING SEASON	Landings (t)	FISHING SEASON	Landings (t)
1975/1976	3,829	1994/1995	9,683
1976/1977	3,525	1995/1996	10,339
1977/1978	2,668	1996/1997	10,646
1978/1979	2,963	1997/1998	12,064
1979/1980	3,203	1998/1999	13,074
1980/1981	3,086	1999/2000	13,444
1981/1982	3,649	2000/2001	16,198
1982/1983	4,546	2001/2002	19,058
1983/1984	5,140	2002/2003	17,613
1984/1985	5,937	2003/2004	17,801
1985/1986	6,892	2004/2005	17,250
1986/1987	7,672	2005/2006	17,009
1987/1988	8,478	2006/2007	16,583
1988/1989	8,200	2007/2008	17,145
1989/1990	9,449	2008/2009	17,262
1990/1991	11,084	2009/2010	19,749
1991/1992	8,888	2010/2011	20,401
1992/1993	8,902	2011/2012	23,292
1993/1994	10,334		

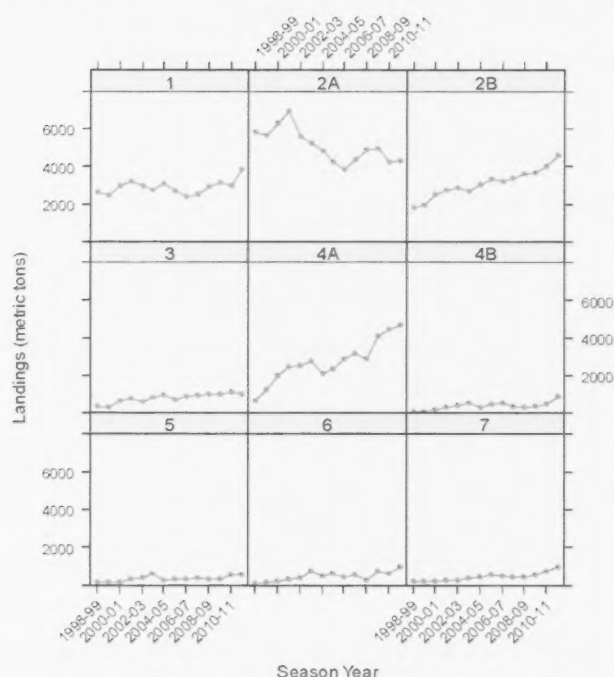


Figure 4. LFA 34 landings from 1998-99 to 2011-12 by Grid Group. Data are from the estimate portion of fishermen logbooks (Lobster Catch and Settlement Reports).

Table 3. LFA 34 landings and effort from nearshore Grid Groups (1, 2A, 2B, 7), midshore Grid Groups (3, 4A, 4B) and offshore Grid Groups (5, 6).

Season	Landings (t)			Effort (number of trap hauls)		
	Nearshore	Midshore	Offshore	Nearshore	Midshore	Offshore
1998-99	10,492	1,140	193	17,625,128	1,599,246	264,058
1999-00	10,225	1,612	267	15,585,435	1,581,669	337,431
2000-01	11,963	2,805	376	16,854,597	2,664,052	326,870
2001-02	13,118	3,528	664	15,704,978	2,711,238	497,379
2002-03	11,643	3,544	724	14,711,306	2,903,055	502,583
2003-04	11,012	4,109	1,343	13,365,064	2,974,154	790,781
2004-05	11,397	3,304	758	15,955,750	3,040,938	684,187
2005-06	10,807	3,560	937	14,668,594	2,846,984	750,733
2006-07	9,947	4,254	787	13,436,048	2,993,134	582,202
2007-08	10,726	4,438	918	16,108,410	3,734,339	720,947
2008-09	11,804	4,197	594	15,593,154	3,569,628	528,926
2009-10	12,266	5,480	1,041	15,139,841	3,786,354	675,250
2010-11	11,943	6,079	1,159	13,137,913	4,334,120	705,496
2011-12	13,735	6,600	1,526	13,977,463	4,289,090	901,397

Fishery Effort

The total annual trap hauls reported for LFA 34 (Figure 5) have no pronounced trend over the period since logbooks were introduced (1998-99). In terms of average days fished, the last 7 years was lower (50-64 days on average) compared to 1998-99 (69 days fished on average). It is concluded that total fishing effort as measured in terms of trap hauls has not increased since 2004/05 or over the last 14 years.

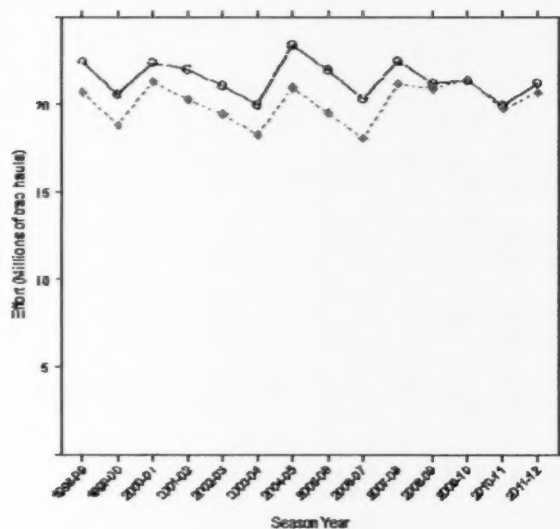


Figure 5. Annual fishing effort in LFA 34 in terms of total annual trap hauls. Data are from the estimate portion of Lobster Catch and Settlement Reports. Solid line is adjusted effort (weightout slip landings/CPUE) and is considered to be the most reliable; blue dashed line is the total from logs.

At the level of LFA 34 Grid Groups, there have been spatial shifts in effort that explain the spatial shift in landings (Table 2, Figure 6). Grid Group 2A, in particular, has seen a drop in effort. Effort in the nearshore portion of LFA 34 in 2011/12 was 88% of that in 2004/05, and 79% of that in 1998/99. Relative to 2004/05 and 1998/99, effort increased in the midshore (1.4 times and 2.7 times) and the offshore (1.3 times and 3.4 times). However, most of the fishing effort (73%) is still in the nearshore.

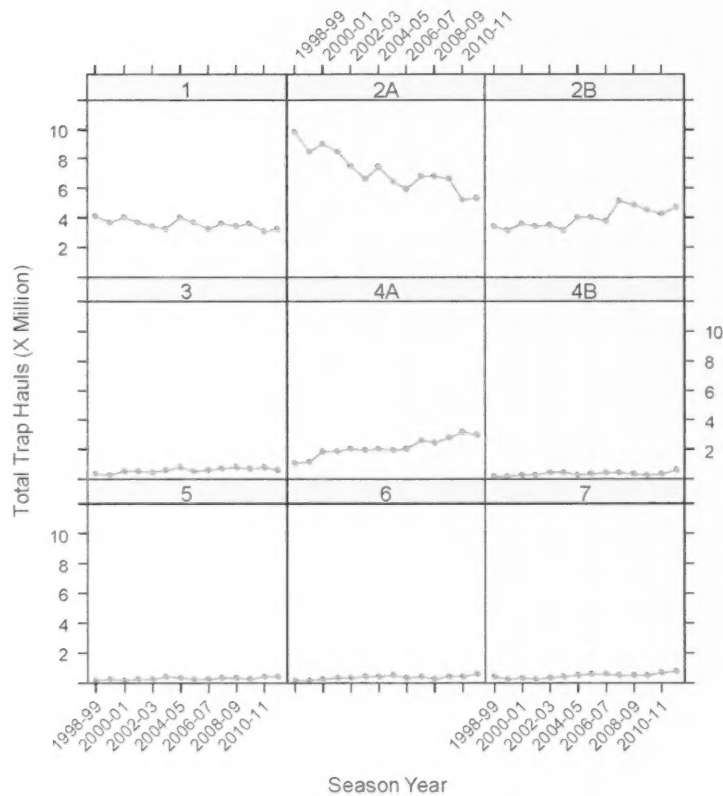


Figure 6. LFA 34 effort (number of trap hauls) 1998-99 to 2011-12 by Grid Group. Data are from the estimate portion of fishermen logbooks (Lobster Catch and Settlement Reports).

Commercial Catch Rate

Commercial catch per unit effort (CPUE) in 2011/12 (1.10 kg/trap haul) increased substantially from 2004/05 (0.74 kg/trap haul) and from 1998-99 (0.58 kg/trap haul). CPUE increased from 1998/99 to 2001/02, declined in 2004/05, remained steady for the next 5 years and increased to new highs in each of the last 3 years (Figure 7). The 2011-2012 CPUE of 1.10 kg/trap haul was the highest in 14 years.

There was a general increase in CPUE in all Grid Groups, particularly in the last 3-5 years (Figure 8). The relative increase in CPUE was highest in the midshore and offshore, and in terms of absolute values, the CPUE has been higher in the midshore and offshore throughout the time period. The higher CPUEs in the midshore and offshore portions of LFA 34 provide an explanation for the shift in effort away from the nearshore.

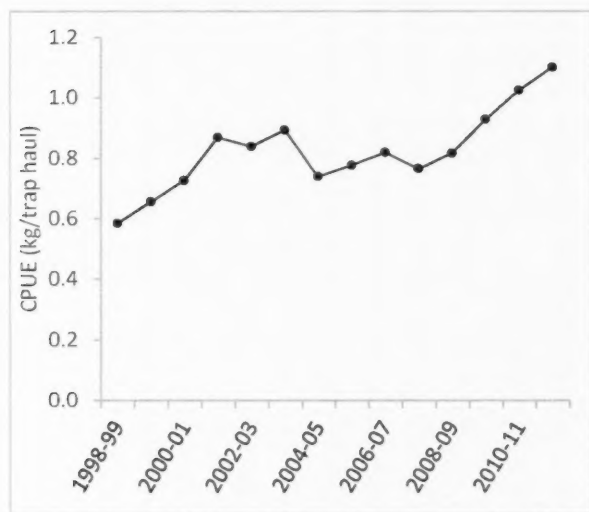


Figure 7. CPUE (kg/trap haul) in LFA 34 as a whole, 1998-99 to 2011-12. Derived from lobster logbooks by dividing total weight landed by total trap hauls for those entries that provided both catch and effort.

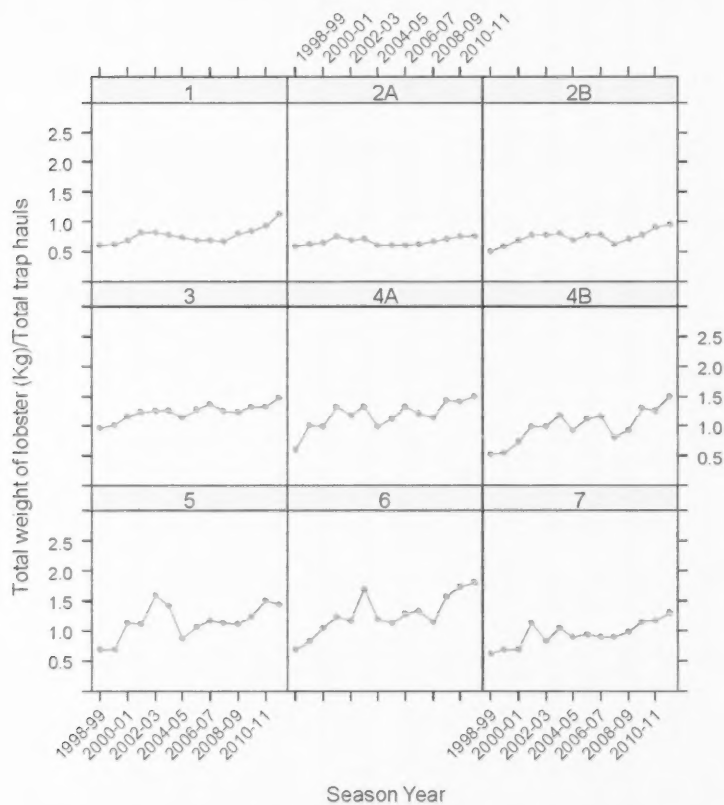


Figure 8. Commercial CPUE (kg/trap haul) within LFA 34 Grid Groups, 1998-99 to 2011-12.

Size in Commercial Traps

As an indicator of fishery performance, size of lobster in commercial traps was estimated for the legal portion of the catch. Considering available at-sea samples from 1989 to the present, the 50th percentiles (median) of female size (Figure 9) have trended downward in some nearshore (Grid Group 2B) and midshore areas (Grid Group 3, 4A). There were downward trends in the sizes of the largest females (95th percentiles) in some nearshore (Grid Group 2B) and the midshore (Grid Group 3, 4A) (Figure 10). Declines in the offshore (Grid Group 5, 6) were not evident and, in fact, there were upward trends. Another source of data for sizes in the commercial catch are the port samples in LFA 34. These are available only beginning in the 2005-06 season. The 95th percentiles of female sizes for port samples from catches in the nearshore, midshore and offshore were highest in the first year (2005-06), with little subsequent trend.

To summarize, downward shifts in size structure were evident for some areas in the nearshore and midshore. There was no indication of a downward shift in the offshore.

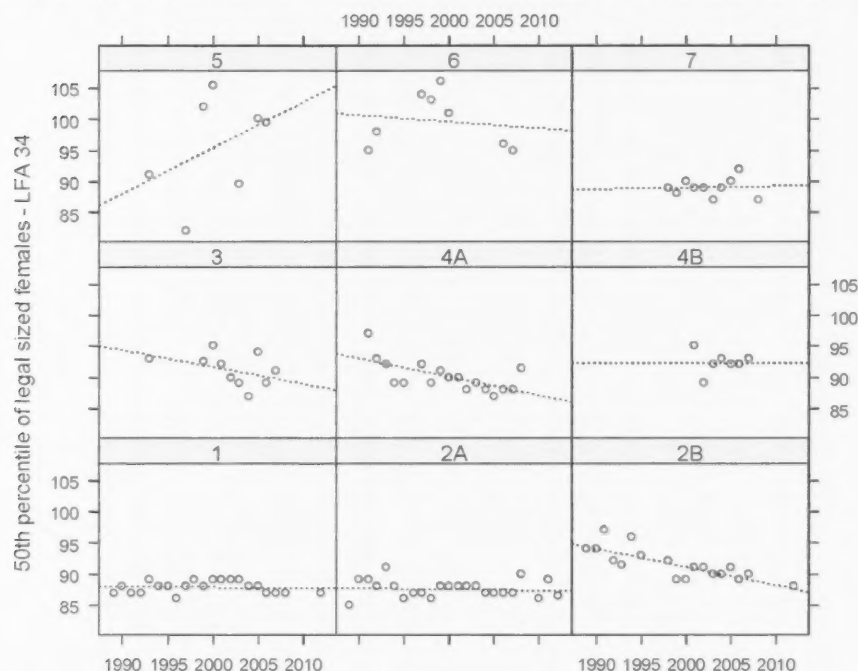


Figure 9. Trends in the median female size lobster from the legal (>82.5 mm) portion of at-sea samples in LFA 34 Grid Groups, 1989-2012. The 50th percentile by year is shown. Dotted line is linear fit.

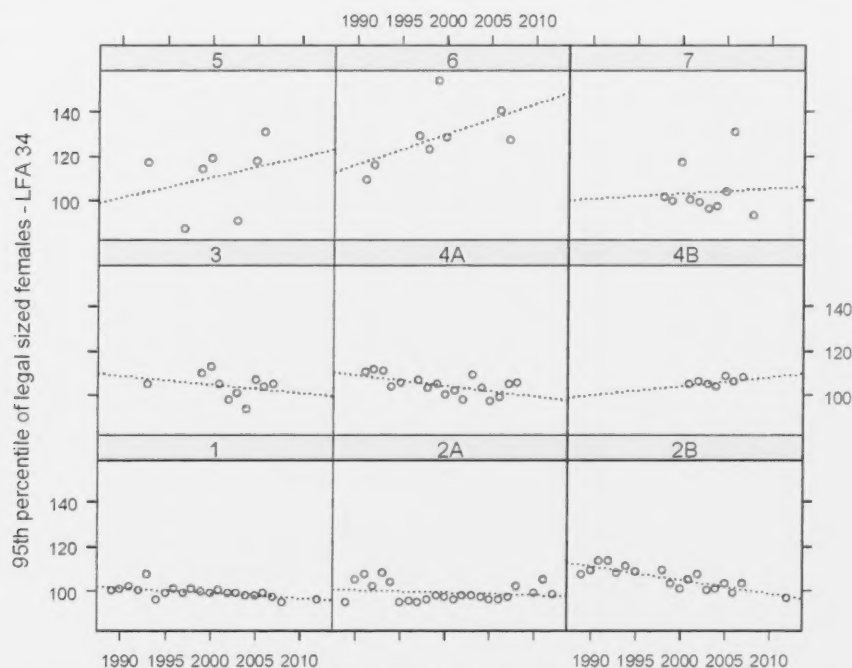


Figure 10. Trends in large female size lobster from the legal (>82.5 mm) portion of at-sea samples. The 95th percentile by year is shown. The dotted line is the linear fit.

Abundance Indicators – Fishery Dependent

Two fishery dependent indicators of the abundance of legal sizes (landings and commercial CPUE, as described above) are at record highs.

The catch rate in FSRs standard traps is considered an indicator of sublegal abundance. While the traps used are not commercial and are designed to retain small lobsters, they are deployed during fishing operations and are, in that sense, fishery dependent. Two approaches were employed: (i) a standardized CPUE (numbers per trap) approach using a Generalized Additive Mixed Model (GAMM), which allows for the incorporation of zeros and using the number of traps hauled as an offset, and (ii) a Temperature Corrected Abundance Index (TCAI) (Allard et al. 2012). This approach uses a probabilistic model and uses temperature-catchability relationships to correct for the effect of temperature on CPUE.

Trends in the standardized CPUE for individual Grid Groups, and for a single index weighted by Grid Group (weighted standardized CPUE), indicate increases in sublegal abundance over the last 1-3 years. The weighted standardized CPUE indicates that CPUE in the nearshore of LFA 34 has been higher in the last 3 seasons (2009-10, 2010-11 and 2011-12) than the average of the previous 10 seasons (Figure 11).

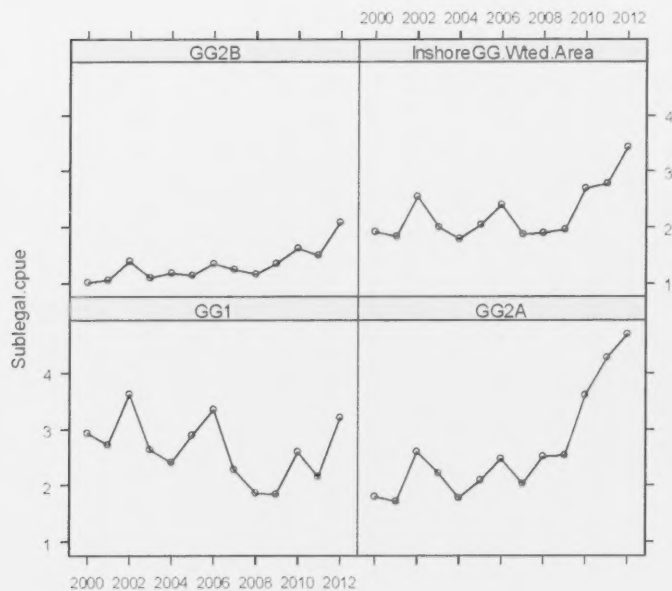


Figure 11. Model predictions of sublegal lobster CPUE in Grid Group (GG) 1, 2A and 2B from a Generalized Additive Mixed Model. "InshoreGG.Wted.Area" plot is a single index based on weighting the predictions for individual GG by their area.

The TCAI index indicates the abundance of sublegal lobsters has been higher in the last 2 seasons (2010-11 and 2011-12) compared to the average of the previous 11 seasons (Figure 12).

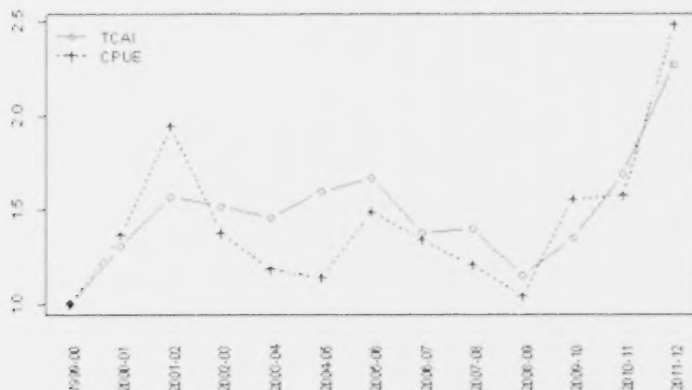


Figure 12. Temperature corrected annual index (TCAI) for sublegal lobsters for combined Grid groups 1, 2A and 2B. Sublegal lobsters are defined as 61-82.5 mm CL (FSRS size classes 7-9 and sublegal portion of 10). Also shown is the non temperature-corrected CPUE. Both series are relative to the first season (1999-2000).

In summary, a standardized CPUE index and a Temperature Corrected Abundance Index both indicate the abundance of sublegal lobsters in the last 2-3 years is the highest since 1999-00.

Abundance Indicators - Fishery Independent Surveys

The summer RV trawl survey is a source of fishery independent information on lobster. The survey has been conducted since 1970. However, nearshore areas (<50 m depth) where lobsters are most abundant are not sampled nor are large areas of LFA 34 due to untrawlable bottom. The increasing trend in the summer RV survey number of lobsters per tow in the Eastern Gulf of Maine area (Browns Bank, Gulf of Maine and Bay of Fundy, RV Strata 480-495, Figure 13) is consistent with the increasing trend in lobster landings in LFA 34 (Figure 14).

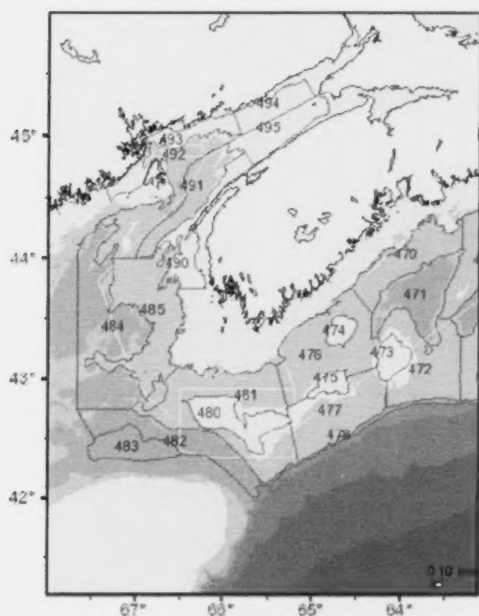


Figure 13. Summer Research Vessel survey strata in the western portion of the Maritimes Region.

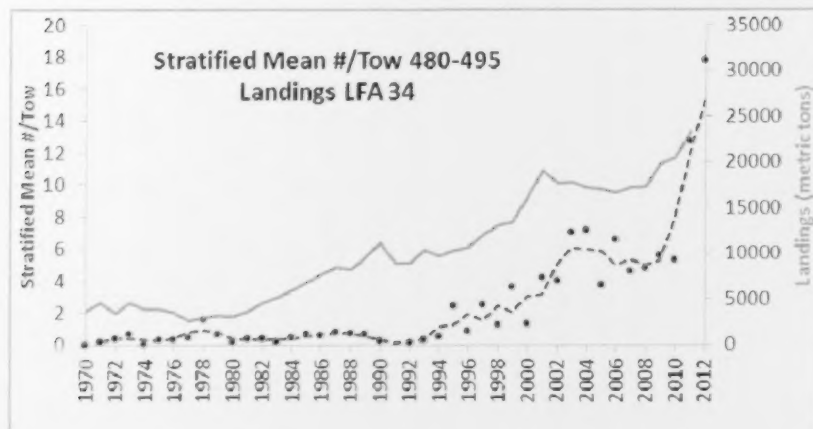


Figure 14. Stratified mean number of lobster per tow (3-year moving average) for Eastern Gulf of Maine (strata 480-495) (blue dotted line), and lobster landings (red solid line) for LFA 34 (1970-2012).

The ITQ survey mean number of lobster per tow is provided as a primary indicator of abundance for LFA 34. This survey began recording lobsters in the first year of the survey (1995) and has recorded lobster sizes since 2005. The ITQ survey is a fixed station survey of approximately 180 stations that occurs at the same time each year (July) (Figure 15). Between 2010 and 2012, 4,000-5,000 lobsters were measured annually during the survey. The mean number of lobster per tow in the ITQ survey in LFA 34 has increased since 2000, with the highest values in the past 3 years (Figure 16).



Figure 15. ITQ survey fixed station locations.

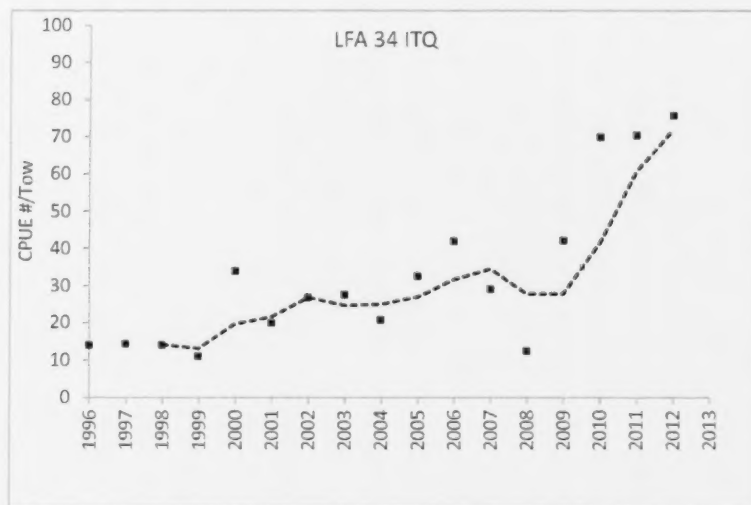


Figure 16. ITQ survey mean number of lobsters/tow and the 3 year moving average (dotted line) for LFA 34. First year of survey (1995) not included as protocols were in development.

There is good correspondence between the trends in the ITQ mean number of lobster per tow, fishery landings and commercial CPUE in LFA 34, with the exception of the nearshore where landings are decoupled from the ITQ index. This is likely due to the shift in the fishing effort from nearshore to midshore.

Catch rates are much higher in the nearshore, as compared to the midshore/offshore (Figure 17), with a mean of over 240 lobsters per tow in each of the last 3 years, compared to 8-15 lobsters per tow in the midshore and less than 5 in the offshore.

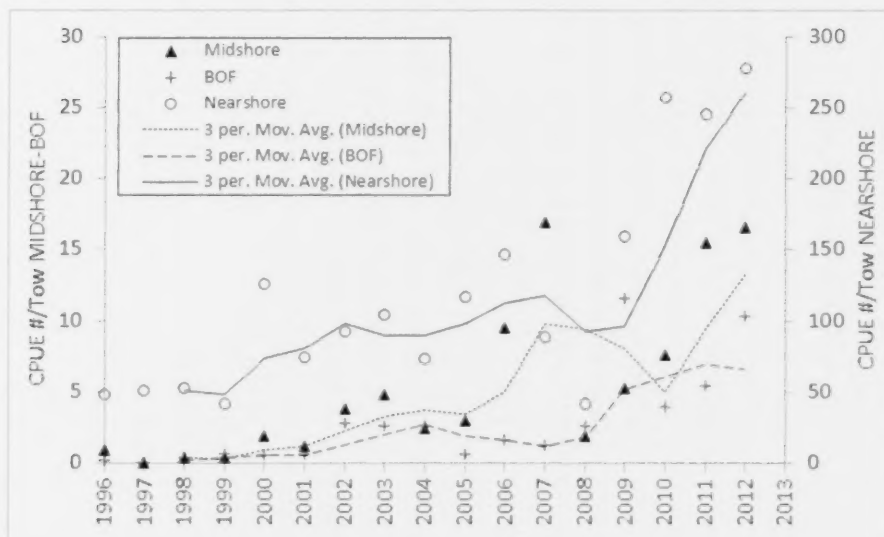


Figure 17. ITQ survey mean number of lobsters per tow and the 3-year moving averages for the midshore, the Bay of Fundy portion of LFA 34 (BOF; Grid Group 7), and the nearshore. Note that scale ranges from 0-300 for nearshore, and 0-30 for midshore and BOF. Offshore not shown (similar trend but always < 5 lobsters per tow).

Scallop survey catch rates of lobsters show trends similar to the summer RV and ITQ surveys where comparisons are possible. The scallop surveys have more limited application as fishery independent indicators of lobster abundance as they have changed in design (spatial coverage, timing) and have lower catch rates of lobsters.

To summarize, the summer RV and the ITQ survey number of lobsters per tow have both increased since 1996. There has been an expansion of the area with lobster catches in the surveys, which suggests a widespread increase in abundance.

Fishing Pressure

The Continuous Change in Ratio (CCIR) method is used to estimate exploitation rate (ER). As this method requires data on sublegal and legal sizes, the FSRs data from LFA 34 were utilized. In addition to CCIR, a size based method (Length Cohort Analysis or LCA) was also used.

CCIR

CCIR estimates ER for a size fraction of the exploitable stock based on the change in ratio of the harvestable fraction to an unharvestable ("reference") fraction. To avoid potential problems with differential catchability, it is best to limit the exploitable sizes to those close to the reference size class. As such, the ER estimates provided here are for lobsters between 82.5 and 90 mm CL, a size fraction that makes up a high proportion of the catch throughout LFAs 34. This size fraction is highly relevant, but it is important to recognize that the CCIR estimates do not include the larger size fractions.

The results for LFA 34 Grid Groups are summarized in Table 3. The ER estimates are shown graphically for males and females in one Grid Group in Figure 18. By Grid Groups the means for 2006-2012 (males and females averaged within year) were 0.87 (GG1), 0.92 (GG2A), 0.80 (GG2B) and 0.87 (GG4AB). The means for 2000-2005 were lower in GG1 (0.79) and GG2A (0.86). Recent estimates are in the upper quartile for the times series for 2 of the 4 Grid Groups, but there was considerable inter-annual variability over the 13 year time series.

All of the exploitation rate estimates for these Grid Groups are high relative to LFAs 27-33. CCIR estimates of exploitation for LFAs 29-32 for the period 2006-2010 averaged 0.57-0.67. For the western part of LFA 33, they averaged 0.72 for the period 2006-2010 (Tremblay et al. 2012).

Table 3. Summary of CCIR exploitation rates for LFA 34 Grid Groups 1, 2A, 2B and 4AB. Shown for each year is the mean of male and female estimates. Each cell is coloured depending on whether it is below the 25th percentile (white), between the 25th and 75th percentiles (grey) or above the 75th percentile (black).

	1	2A	2B	4AB
2000	0.90	0.81	0.80	NA
2001	0.67	0.76	0.79	NA
2002	0.85	0.89	0.83	NA
2003	0.71	0.92	0.71	NA
2004	NA	NA	NA	NA
2005	0.82	0.90	0.82	0.861
2006	0.88	0.93	0.63	0.778
2007	0.89	0.89	0.94	0.91
2008	0.73	0.96	0.79	0.873
2009	0.90	0.92	0.72	0.821
2010	0.91	0.91	0.81	0.86
2011	0.91	0.90	0.74	NA
2012	0.87	0.95	0.81	0.88
25 th percentile	0.80	0.89	0.74	0.84
75 th percentile	0.89	0.93	0.82	0.88
Mean 2000-2005	0.79	0.86	0.79	0.86
Mean 2006-2012	0.87	0.92	0.80	0.87

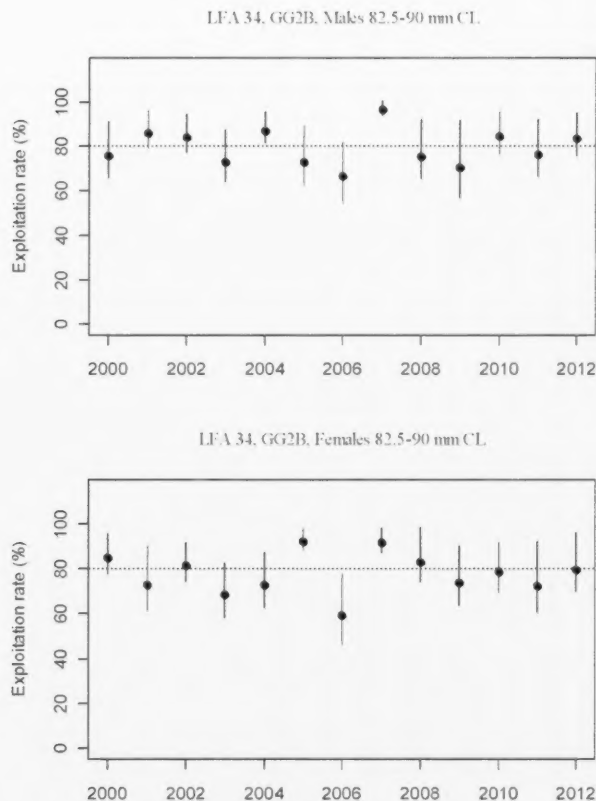


Figure 18. CCIR results for male and female lobster in Grid Group 2B, 1999-2000 to 2011-12. Dashed line at Exploitation=80% is for reference only.

Length Cohort Analysis

LCA utilizes information on the size structure and the time spent within size intervals (cohorts) based on growth rates. The concept is that if there is a steep decline in numbers (or percentage) with increasing size, then mortality is higher than if there is a more gradual decline. Assumptions are made regarding lobster movement and the natural mortality of lobsters. Since this method does not follow a single cohort over time, but instead assumes that the size frequency represents the abundance of a cohort over time, the method assumes constant recruitment. In practice, however, this is not the case and estimates are generally based on the mean of several years. In conditions where the recruitment is dramatically changing year to year, such values should be used with caution. Similarly, where changes in fishing patterns result in changes in the mix of sizes in the catch, estimates of exploitation rate will be affected. For example, an increase in fishing effort in deeper water areas with a large mean size could result in a lower estimate of exploitation rate.

The analysis was done on the weighted catch of females at size for the season 2000-01, 2003-04, 2006-07 and 2009-10. The size frequencies for the above seasons were based primarily on sizes measured during the above season but, where Grid Groups were not sampled in that season, seasons before or after were used to fill in the gaps.

The LCA results for the four seasons in LFA 34 are shown in Table 4. Size data were available for the whole of LFA 34, so estimates were done by nearshore, midshore and offshore. The results indicate differences between males and females and between nearshore, midshore and offshore, but there is no indication from LCA of an increase in exploitation rate over the time period considered. Estimates of exploitation were highest in the nearshore (females=0.84), almost as high in the midshore (females=0.76-0.80) and lowest in the offshore (0.47-0.49). For LFA 34, the overall estimates were 0.80 for females.

A truncated size distribution observed in the nearshore for decades suggests that exploitation rates have been high nearshore for many years.

To summarize, exploitation rates in LFA 34 overall (0.8 for females) have not increased since 2000-01, but are high relative to other lobster assessment areas and may have increased relative to the early 1990s. There is mixed evidence for increased exploitation in the nearshore in the last 10-12 years; CCIR indicates an increase in two nearshore Grid Groups, while LCA indicates no increase. Exploitation rates are highest in the nearshore (0.8 to 0.9 for females) and appear to have been high for many years; exploitation rate is lower in the offshore portion of LFA 34 (0.49 for females) and has not increased since 2000-01.

Table 4. Female lobster exploitation rate estimates from Length Composition Analysis (LCA) for LFA 34. Nearshore includes Grid Groups 1, 2A, 2B and 7; Midshore includes Grid Groups 3, 4A and 4B; Offshore includes Grid groups 5 and 6.

Fishing Season	Nearshore	Midshore	Offshore	All of LFA 34
2000-01	0.83	0.79	0.47	0.81
2003-04	0.85	0.81	0.47	0.79
2006-07	0.85	0.84	0.44	0.83
2009-10	0.84	0.67	0.54	0.77
Mean 2006-10	0.84	0.80	0.47	0.80
Mean 2000-04	0.85	0.76	0.49	0.80

Reproduction

Size at onset of 50% maturity (SOM50) for 2011 was estimated at 96.5 mm CL in Lobster Bay (GG 2A) (Figure 19), which is similar to a previous estimate of 95 mm CL. Only a small portion of females below the minimum legal size reach maturity.

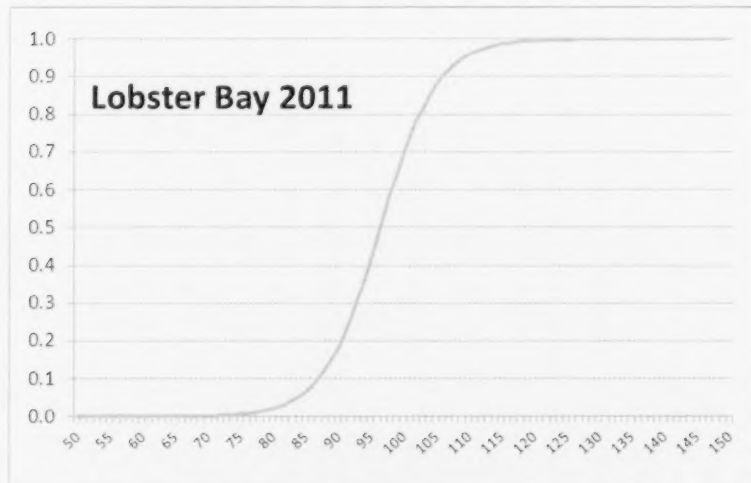


Figure 19. Maturity ogive for female lobster in LFA 34 (Lobster Bay) based on samples in 2011. Large females assessed as immature were excluded.

While the SOM50 may have been stable, there have been subtle changes in the size of ovigerous females caught in commercial traps. There has been a slight downward trend in the size of the smallest ovigerous females caught in traps.

Despite increases in lobster abundance, the potential and observed egg production indices for subareas of the nearshore and midshore (Grid Groups 4A and 2A) for the most recent time period showed no increase relative to the 1990-1995 time period (Figure 20). In Grid Group 4A, the size category that contributed the most to the reproductive potential shifted down from medium size (100-120 mm CL) to lobster smaller than 100 mm CL. In Grid Group 2A, the medium size was also the biggest contributor to reproductive potential and observed egg contribution historically, but its contribution was substantially lower for the most recent period. In the adjacent Bay of Fundy, it has been shown that contribution to egg production from smaller mature females may be disproportionately low because of lower mating success. Those results reinforce the importance of larger individuals (i.e. larger than SOM50) for maintaining healthy broodstock.

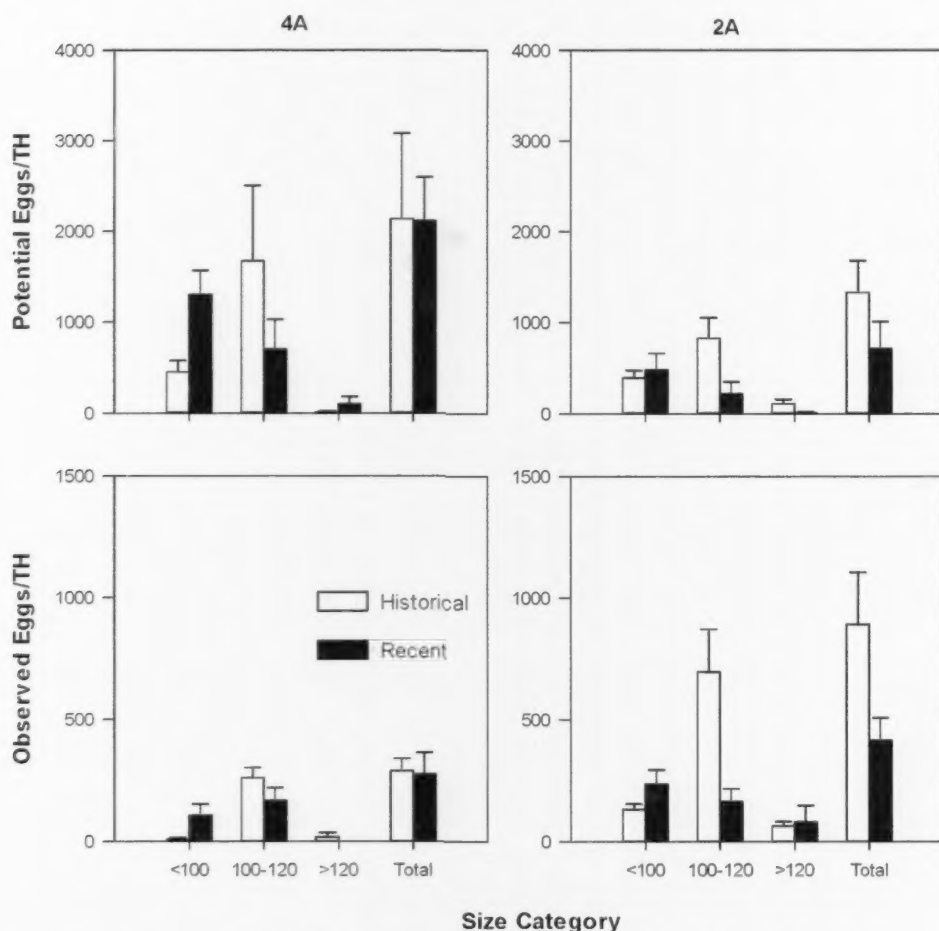


Figure 20. Average ($\pm$ standard error) egg production potential (top panels) and observed egg production (lower panels) for four size categories (Small: <100mm; Medium: 100-120mm, Large: $\geq$ 120mm CL) during two time periods in Grid Groups 4A and 2A.

Ecosystem Considerations

Temperature

The North Atlantic Oscillation (NAO) plays a major role in year-to-year changes in ocean climate off eastern US/Canada. In the past, the NAO Index has been considered a potential predictor of temperature in the following 2+ years, with a low NAO index often resulting in lower temperatures on the southwest Scotian Shelf and Bay of Fundy. However, a very low 2010 NAO index resulted in very warm 2012 temperatures, the warmest on record, throughout the region and throughout the water column (up to 2 degrees higher than average in some places). In 2012, the NAO index was high. Based on previous patterns in the NAO, warmer than average water temperatures might be expected in LFA 34 in the next few years. In terms of longer term trends in temperature, there is a slightly increasing trend in the Bay of Fundy that may be significant, but the Halifax station indicates no long term trend in temperature.

Predation

The increase in lobster abundance in the Gulf of Maine has been hypothesized to be a release from predation by groundfish and/or a shift to a more favorable climate. Known and suspected predators of lobsters include cunners, longhorn sculpins, skates, cod, spiny dogfish, sea ravens, wolfish, haddock, hake, crabs, and seals. Predation rates are highly size-specific and decline as lobsters get larger. The trend in the summer RV survey biomass indices for potential predators of lobster indicate most are at low levels relative to their long-term means (Table 5). The exception is sea raven, which is well above its long term mean. Atlantic wolfish and cod are both low, at 4% and 13%, respectively, of their long-term means (1970-2009). The recent summer RV survey index for haddock is closer to its long-term mean but still below. Recent summer RV survey indices for cusk, spiny dogfish, white hake and longhorn sculpin, are at 30-64% of their long-term means.

Given the current low summer RV survey indices for most of these potential lobster predators, a near-term increase in the natural mortality of lobsters in LFA 34 due to these species is not expected. Although the RV survey does not cover much of the nearshore grounds where lobsters are most abundant, trends in the biomass indices for some of these species in the ITQ survey are similar.

Table 5. Summer RV survey biomass index (t) of potential predators of lobster. Long term mean estimates and the estimates for recent years as a percentage of long-term values are shown. The area used to calculate the survey indices was North Atlantic Fisheries Organization subdivisions 4Xopqrs.

Species	Long-term mean 1970-2009	Recent mean 2010-2012	Recent mean as % of long-term mean
Atlantic Wolffish	861	33	4%
Cod	13,410	1,718	13%
Cusk	2,166	464	21%
Haddock	21,240	15,141	71%
Longhorn Sculpin	1,195	759	64%
Sea Raven	1,468	1,916	131%
Spiny Dogfish	79,821	28,291	35%
White Hake	16,437	8,966	55%

Incidental Catch

The Maritime Region lobster fishery (LFA 27-34 and 41) was sampled for levels of incidental catch and discards during 2009-10. In LFA 34, observers made 288 trips on 187 vessels, with a total of 116 t of lobsters recorded. Species were identified, weights estimated and lobsters and important species of fish measured. Observed weights were expanded to total weight using the ratio of observed weight of incidental species to lobsters and total landings, weighted by season (fall, winter, spring) and area (nearshore, midshore, offshore).

Estimates of incidental catch, including discarded and retained catch of the 50 species identified, was 5,430 t. The main species caught as incident catch in the fishery were those that can be retained for bait and sale: Jonah crab (2,005 t), and rock crab (911 t), of which males may be retained, and various sculpin/sea raven species (987 t). Other major species included cusk (219 t), cod (211 t), hermit crabs (637 t) and whelks (335 t). The total incidental

catch and incidental catch of non-retainable species represent 15% and 4.2% of the total lobster landings respectively.

Lobster <82.5 mm CL, egg bearing females, and V-notches females must be returned to the water (discarded); these lobster discards (post-release survival known to be high) were estimated at 0.7 kg for each 1.0 kg of lobster landed or 14,634 t (2009-10). Undersize lobsters account for approximately 97% of the lobster discards.

Fishery Footprint

LFA 34 encompasses approximately 20,000 km². The area affected by lobster traps ("fishery footprint") on an annual basis in LFA 34 was estimated using the number of trap hauls per season times the area of a typical lobster trap. This was then divided into the total area of LFA 34. The same calculation was done per each LFA 34 Grid Group. The trap size used was 21"x48" (American style trap), which does not account for movement of the traps. However, the analysis assumes that traps are dropped in a new location each time, which does not account for the expected overlap in trap footprints over time. The area affected by traps in any given year in LFA 34 as a whole is calculated to be less than 0.1% of the total area; in the nearshore Grid Groups, the total area affected is higher but still less than 0.2% of the total area.

Reference Points

A precautionary approach proposed for lobster in LFA 34 utilizes reference points for the abundance of legal sizes (landings, commercial catch rate) and the abundance of legal and sublegal sizes combined (ITQ survey). These indicators are above their Upper Stock References (USR), indicating that the lobster stock in LFA 34 is in the healthy zone.

Landings-based reference points for the abundance of legal sizes are based on the median of the lobster landings from 1985-2009 as a Biomass at Maximum Sustainable Yield (B_{MSY}) proxy (Tremblay, Pezzack and Gaudette 2012). For the upper stock reference (USR) and limit reference point (LRP), the values of 80% and 40% were selected. For LFA 34, the USR is calculated to be 8,867 t. The metric for assessing where the stock is relative to the reference points is the 3-year running average of landings. This metric is 21,147 t for the season ending 2011-12, putting LFA 34 lobster in the healthy zone, well above the USR.

A USR for abundance of legal size lobsters based on the commercial CPUE for LFA 34 as a whole is proposed (Figure 21). While there have been spatial differences in CPUE trends within LFA 34, all Grid Groups have trended upwards in the last 14 years and the trend in the raw CPUE is expected to reflect the trend in most subareas. It is proposed that the median CPUE for the period 1998-99 to 2008-09 (= 0.78 kg/trap haul) be used as a proxy for B_{MSY} . This period covers much of the available time series for CPUE, considered a productive period, but it does not include the last 3 record-breaking seasons. A USR equal to 80% of the median (=0.62 kg/trap haul) is proposed. This USR is close to the CPUE measured at the start of the CPUE time series (1998-99, CPUE = 0.58 kg/trap haul). The metric for assessing where the stock is relative to the USR is the 3-year running mean of the commercial CPUE. The current 3-year running mean (1.0 kg/trap haul) is well above the proposed USR.

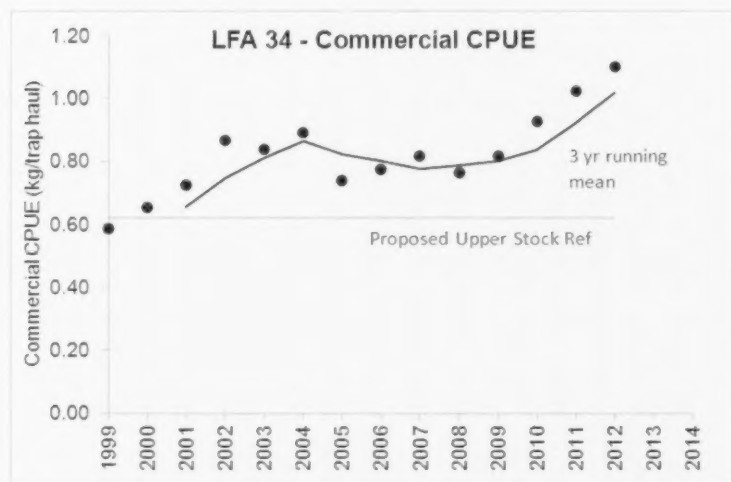


Figure 21. Proposed Upper Stock Reference (USR) (horizontal line) based on commercial CPUE for LFA 34. Shown is annual commercial CPUE (total weight landed/total trap hauls), with USR based on 80% of the median CPUE from 1998-99 to 2008-09 (=0.62 kg/trap haul). Also shown is the 3 year running mean (= 1.0 after 2011-12 season).

A proposed fishery independent USR for legal and sublegal lobster abundance is 80% of the median catch rate in the ITQ survey for the period 1996-2009 (Figure 22). The period 1996 to 2009 is proposed to avoid the initial year that involved protocol development. The end year (2009) is consistent with the landings-based reference points. The median of the above period (23.7 lobster per tow) is proposed as a B_{MSY} proxy, and a USR of 80% of this (19.0 lobsters per tow) is suggested. As for the previous USRs, it is proposed that the 3-year mean be used as the metric to assess stock status in relation to the reference point. The current 3-year mean (71.9) is well above the proposed USR.

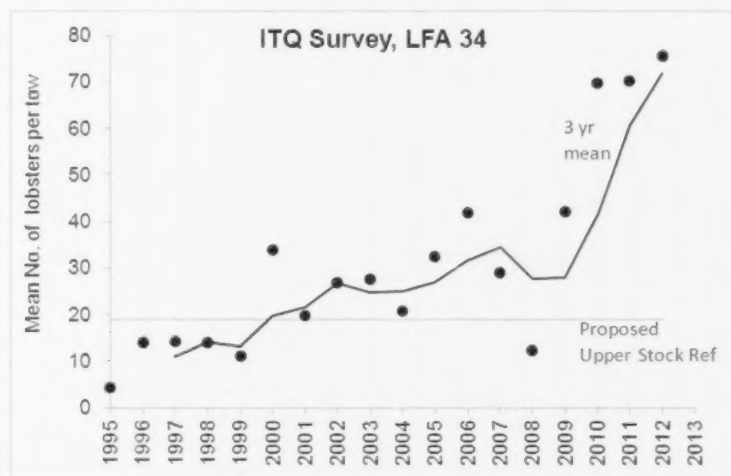


Figure 22. Proposed Upper Stock Reference (USR) for lobster abundance in LFA 34 based on ITQ survey. The median for 1996 to 2009 (23.7 lobsters/tow) is used as the B_{MSY} proxy, with the USR proposed as 80% of the median (19.0 lobsters/tow, dashed line). The solid line is the 3-year running mean.

Secondary indicators may both change the perception of stock status and inform the type of response to a stock that has entered the cautious zone (Tremblay et al. 2012). The primary indicators need to be interpreted in the light of secondary indicators related to Abundance/biomass (commercial sizes), Production (recruitment, reproduction), Demography (size structure, sex ratio), Fishing Pressure (effort, exploitation) and the Environment. Spatial changes in distribution should also be considered. For example if the ITQ trawl catch rate for LFA 34 declines, the changes within the Grid Groups should be examined. While these secondary indicators will not necessarily be evaluated on an annual basis, they will be evaluated should the primary indicators change substantially. The reduction in the contribution of larger lobsters to reproduction is an aspect that needs to be monitored at the level of the secondary indicators.

Sources of Uncertainty

It is assumed that the subset of commercial fishing logbooks with useable data is representative of all logbooks. This is reasonable given that useable records in recent years accounted for upwards of 80% of all records and catches and 90% of all effort.

Landings are a function of abundance, the level of fishing effort (trap hauls, soak-days, timing of effort and fishing strategy) and catchability. Catchability in turn is affected by environmental conditions, gear efficiency including trap design and bait, and other factors. Changes in any of these can affect landings and catch rates. Thus, landings do not necessarily reflect the changes in abundance. Area-specific commercial CPUE should be more closely related to true abundance but will still be affected by catchability.

Any changes in fishing efficiency (or "effective effort") have not been accounted for here. If fishing efficiency has increased since the last assessment (2006) due to larger vessels, better navigation or improved fishing strategy, then commercial CPUE may inflate the perception of abundance in recent years. Given that the catch rate of lobsters in fishery independent surveys has showed a trend similar to that based on commercial logbooks, recent changes in fishing efficiency are unlikely to be important to the perception of abundance.

The fishery independent surveys show abundance trends similar to those seen in fishery dependent data, but examination of size structure in the trawl catch has not detected changes over the last 10 years as might be expected given a surge in recruitment. In addition, there is interannual variation in the number of lobsters per tow that is reflected in both sublegal and legal size lobsters.

FSRS traps are limited to nearshore areas and may not represent the sublegal sizes in the midshore and offshore areas.

Methods of estimating exploitation rates have various assumptions, not all of which are met in the applications here. The methods are robust to some violations of assumptions but not all have been examined here. The methods used here should be reliable for measuring trends over time.

CONCLUSIONS AND ADVICE

Abundance of lobsters in LFA 34 is near record highs. Environmental conditions for lobster production appear very favorable. Exploitation rate has been stable for 10-12 years but is high relative to other stock assessment units. High exploitation rates in the nearshore portion of LFA 34 have not inhibited the substantial increases in abundance in the last 10-12 years. Given that the environmental conditions remain favorable for lobster, the current levels of fishing effort do not appear to threaten the sustainability of lobster stocks in LFA 34. The percentage of reproduction contributed by larger females (>100 mm CL) is low and has likely declined relative to 20 years ago. Since it is uncertain how long favourable conditions will continue, consideration should be given to implementation of measures that increase egg production from larger sizes. Such measures can improve stock resilience if conditions become less favorable for lobster production.

OTHER CONSIDERATIONS

Although current exploitation rates are unlikely to threaten sustainability of lobsters in LFA 34 under current conditions, through "recruit overfishing", lower exploitation rates would very likely increase yield per recruit. Previous estimates of yield per recruit for some of these LFAs (Miller et al. 1987, Idoine et al. 2001) indicated yield per recruit would increase with decreased effort or increased minimum legal size. A yield per recruit analysis was outside the scope of this assessment and would have to account for changes since the last analysis, such as updated values for size at maturity. Potential density dependent effects on growth and maturity would also need consideration. Economic considerations could also be built into the analysis.

The future of surveys, particularly fishery independent surveys, to support the indices and ongoing evaluation of stock status is uncertain. If these were to change, indicators and reference points may need to be re-evaluated.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 12-14, 2013, Review of Framework and Assessment for LFA 34-38 Lobster Stocks: Part 2 - Assessment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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ISSN 1919-5087
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Correct Citation for this Publication:

DFO. 2013. Assessment of Lobster (*Homarus americanus*) in Lobster Fishing Area (LFA) 34. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/024.

Aussi disponible en français :

MPO. 2013. Évaluation du homard (*Homarus americanus*) dans la zone de pêche du homard (ZPH) 34. Secr. can. de consult. sci. du MPO, Avis sci. 2013/024.